TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 651

EFFECT OF SPARK-TIMING REGULARITY ON THE KNOCK LIMITATIONS OF ENGINE PERFORMANCE

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SUMMARY

Tests on a high-speed single-cylinder engine are described. The regularity of the spark timing was varied by driving the timer from different engine shafts. A simple and reasonably accurate method of determining the spark timing is described. The results show that irregular spark timing may cause large errors in tests of the knocking properties of fuels. For the engine tested, it was found that a change of one crankshaft degree in spark retard was equivalent to an 0.85 inch of Hg change in allowable inlet pressure.

INTRODUCTION

The effect of spark timing on the phenomena of fuel knock is generally known. For an engine operating near the knocking limit of the fuel and for which the spark timing is set for maximum power, any slight spark advance in any cycle may cause knock during that cycle. Audible knock may occur as sharp "pings" at infrequent intervals, depending upon the variance in the spark timing. The knock of engines in which the spark timing is quite regular is noticeably more consistent and its boundaries are more sharply defined than that of engines with irregular timing. From practical considerations, an infrequent knocking cycle may not be harmful in itself. Knock of any kind, however, may cause a gradual temperature rise of critical surfaces in the combustion chamber and may thereby cause surface ignition or lead to a continuous and more severe form of knock; for this reason, knock should be avoided. If engine operation is limited to the nonknocking power range, the inlet pressure and, consequently, the power can be increased by improving the regularity of the spark timing.

Variations in spark timing may result from inaccurate timer cams, bouncing of the breaker points, looseness in the mechanism, or from a nonuniform rotation of the timer cam caused by torsional vibration in the drive system. Some of these difficulties can be readily detected by means of a stroboscope. The ignition timers of single-cylinder test engines are usually driven from the camshaft or from one of the gears in the camshaft-drive system. These locations, in most cases, make for simplicity but are usually poor choices for obtaining regular spark timing.

The increase in permissible engine power with improvement in the regularity of the spark timing was forcibly indicated during a recent investigation. The information obtained is presented to show the importance of accurate spark timing. In addition, a simple method is suggested for determining the timing accuracy.

APPARATUS AND TESTS

The tests were conducted with a high-speed single-cylinder test engine of 5-inch bore and 5.75-inch stroke. With the exception of the cylinder head, the engine and auxiliary apparatus were the same as described in reference 1. The cylinder head is of the pent-roof type having two intake and two exhaust valves, which are operated from a single overhead camshaft driven from the crankshaft by means of spiral bevel gears. In the original set-up, the ignition timer, shown in figure 1, was driven directly from one end of the camshaft. In the final set-up, the timer shown in figure 2 was driven directly from the gear end of the crankshaft.

In the conventional ignition system, the duration of the spark extends for a considerable period in terms of crankshaft degrees of a high-speed engine. The breakdown voltage required to establish the initial arc is considerably higher than the voltage available to maintain the arc. Oscillographs of the spark show this initial peak voltage to be followed by oscillations of diminishing intensity (reference 2). If it were not for the oscillations that follow the initial arc, it should be quite possible to determine the regularity of the timing by any one of several types of stroboscope. For this reason, the following method for determining the regularity of the spark timing was used.

The spark was caused to puncture combined thicknesses of paper and layers of cellophane tape fixed to the circumference of the flywheel. The dielectric strength of this recording strip was made just sufficient to quench the spark after the arc was established. The paper used in this strip served for recording the spark punctures as the punctures made in the cellophane tape proved to be self-closing. This arrangement was checked by operating an accurate timer from a large motor. All sparks were found to pass through a single hole in the recording strip. The sparking electrode was then moved in the direction of rotation of the recording strip to determine the movement required before the spark would puncture a new hole through the strip rather than jump back through the initial hole. At a flywheel speed of 2,500 r.p.m. or a surface speed of 3,010 inches per second, it was found that a new hole was punctured when the electrode movement was $3/4^{\circ}$ or 0.15 inch, thus making the measurement accurate to within $\pm 3/4^{\circ}$. For high-speed engines it will generally be difficult to obtain more accurate timing than $\pm 1^{\circ}$. The method therefore appears to be sufficiently accurate for most purposes, provided that the surface speed of the recording strip is sufficiently high.

The tests were made with a compression ratio of 8.0 at an engine speed of 2,500 r.p.m. The inlet-air temperature and the coolant temperatures were held constant at 200° F. and 250° F., respectively. The mixture was held constant at an air-fuel ratio of 12.2, which is the mixture ratio for maximum power for the foregoing conditions.

Tests were first made with the ignition timer operating from one end of the camshaft. It was subsequently found that these tests had been made with a slight looseness of the gear on the camshaft drive. The dispersion of the sparks on the record with this set-up was within ±5 crankshaft degrees. The dispersion after the gear was tightened was slightly reduced. The timer was then driven from the gear end of the crankshaft through an accurately fitted differential-type reduction gear. The dispersion with this arrangement was within ±2 crankshaft degrees. Owing to the fact that any looseness in the timer drive when operating at crankshaft speed causes only half the error obtained at camshaft speed, it was decided to make the final drive direct from the gear end of the crankshaft. The final arrangement of the drive gave a spark dispersion of ±3/4 crankshaft degree. The original timer mechanism proved to be too slow for a cam speed of 2,500 r.p.m. and was replaced by the design shown in figure 2. The modified timer was satisfactory in operation at very high cam speeds.

RESULTS

The curves in figure 3 show the effect of accurate ignition timing on the nonknocking limit of technical iso-octane plus 1 ml of tetraethyl lead. The curves marked A indicate the highest allowable intake pressure and the resulting i.m.e.p. for the condition of incipient knock at various spark settings when the regularity of the ignition timing lies within ±5 crankshaft degrees. The curves marked B give the same information for the case in which the timing is within ±3/4 crankshaft degree. The improvement in allowable boost pressure amounts to approximately 7 inches of Hg at a spark setting of 27° advance. This setting is the timing for maximum power for these operating conditions. The corresponding change in i.m.e.p. was from 133 to 183 pounds per square inch. Maximum engine power for constant inlet-air pressure was practically unaffected by improving the regularity of the spark timing.

The curves in figure 3 also show the very noticeable effect of spark advance on the allowable inlet pressure. For curve B the inlet pressure changes approximately 0.85 inch of Hg per degree spark retard.

During the previously mentioned tests, the knock in any cycle was indicated by a vertical rise on the otherwise horizontal trace of a cathode-ray tube oscillograph. The height of this vertical line for the condition of incipient knock, which was used throughout these tests, was approximately one-eighth of the height of this line for audible knock. The indicator showed a marked difference between knock with regular and with irregular spark timing. Irregular timing produced erratic cyclic variations in the knock indication; whereas, regular timing showed more consistent results. In addition to this method of visually observing the intensity of knock, an M.I.T. knockmeter was used. This instrument indicates an average value of knock. A severe but intermittent form of knock, which may be the product of irregular spark timing, may give the same indication with this type of instrument as a continuous but very light or incipient form of knock, which may be the product of very regular spark timing. The indications from this type of meter, unlike those from visual knock-indicating devices, do not differentiate between regular and irregular knock such as might be obtained with different degrees of spark-timing accuracy.

CONCLUSIONS

1. Irregular spark timing may appreciably reduce the nonknocking power range of an engine.

2. In the tests described, a change of one crankshaft degree in spark retard was equivalent to an 0.85 inch of Hg change in allowable inlet pressure.

3. Irregular spark timing may cause large errors in tests of the knocking properties of fuels.

4. Spark-timing errors can be determined with reasonable accuracy by causing the spark to puncture combined thicknesses of paper and cellophane tape attached to the engine flywheel.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., May 9, 1938.

REFERENCES

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2. Fitzsimmons, J. T.: Ignition Requirements for High-Compression Engines. S.A.E. Trans., vol. 24, 1929, pp. 301-309.

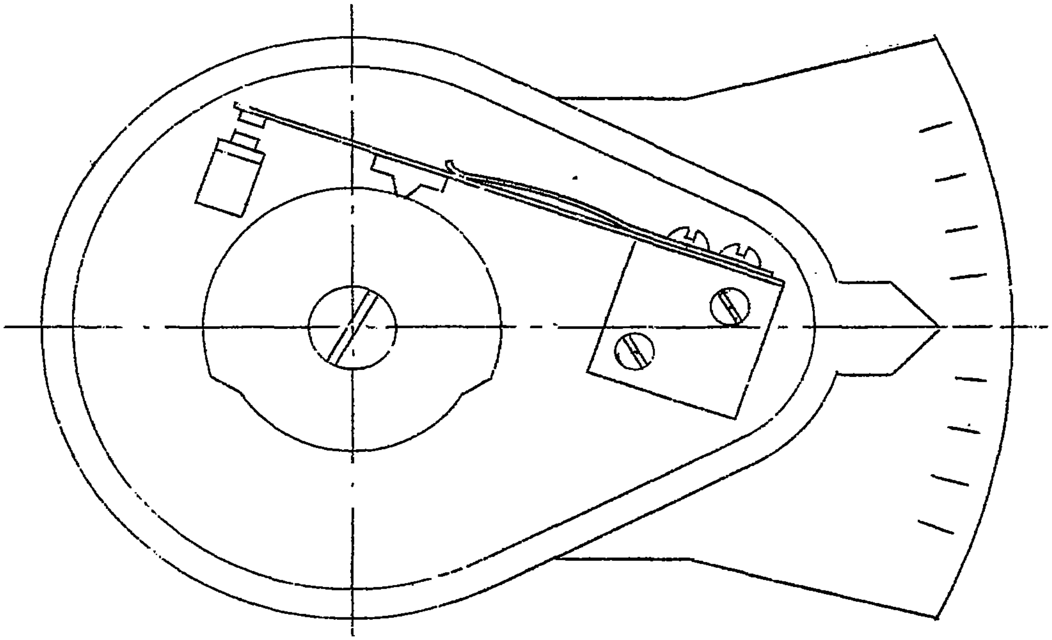

Figure 1.- Original timer.

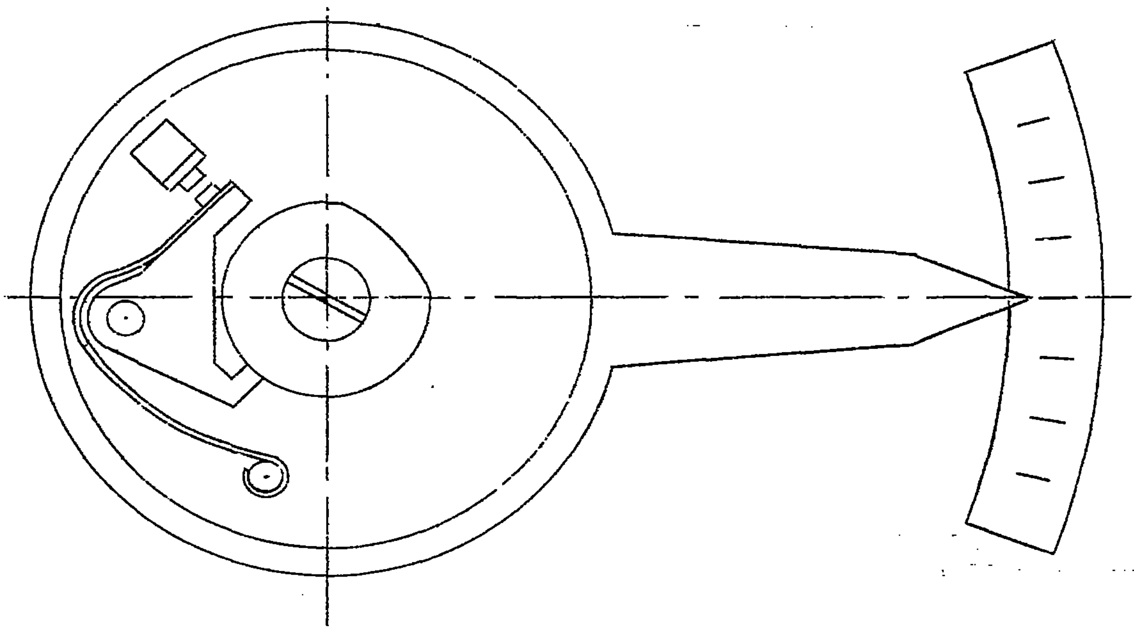

Figure 2.- Improved timer.

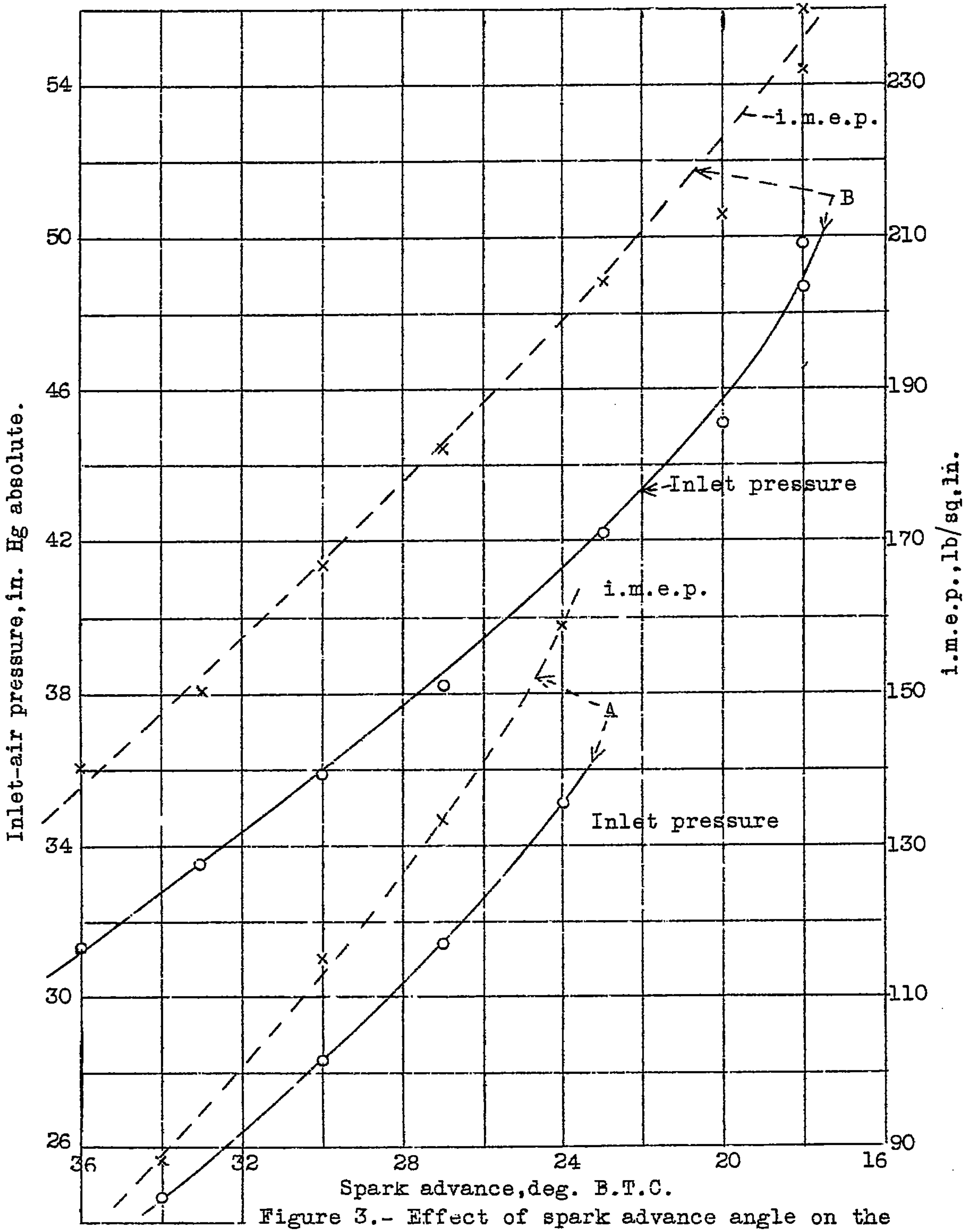

Figure 3.- Effect of spark advance angle on the maximum engine performance with incipient knock Spark dispersion for A was within ± 5 crankshaft degrees; for B, within $\pm \frac{3}{4}$ crankshaft degree.